CHAPTER TEN

Integrated Restoration

TOGETHER WITH THE BAYLANDS ECOSYSTEM Habitat Goals Project and the Uplands Habitat Goals Project (see box below), the Subtidal Goals Project represents a milestone in regional habitat planning for San Francisco Bay and its watersheds. We now have a comprehensive and innovative ecosystem-based management vision for a continuum of habitat types from the bottom of the bay to tidal wetlands and grassland transition zones to upland areas. Each goals report outlines recommendations for the preservation, restoration, and protection of habitat. These reports provide important tools to educate agencies, non-profits, private foundations, and others about the value of these habitats, and offer background information that can be used to seek funding for implementation. Although at present these three goals projects are proceeding independently of each other, there may be

RELATED REGIONAL PLANNING EFFORTS

Baylands Habitat Goals Project

The Baylands Ecosystem Habitat Goals Project, completed in 1999, used available scientific knowledge to identify the types, amounts, and distribution of wetlands and related habitats needed to sustain diverse, healthy communities of fish and wildlife resources in the San Francisco Bay Area. It provided a biological basis for a regional wetlands planning process to assist public and private interests seeking to preserve and restore the ecological integrity of wetland communities. Remarkably successful at articulating a vision for protecting and restoring 100,000 acres of wetland habitat, its report informed stakeholders about the importance of wetland habitat and the need for future funding.

By November 2010, more than 40,000 acres of tidal wetlands had been acquired for restoration by private, local, state, and federal partners. Many agencies and non-profit organizations have participated in implementing report recommendations. For example, the San Francisco Bay Joint Venture (SFBJV) is helping coordinate implementation of some recommendations with local, state, and federal partners, and has developed an Implementation Strategy based on the recommendations. With its partner database, the SFBJV has been tracking progress towards tidal wetland acquisition, planning, and restoration. The State Coastal Conservancy is currently planning an update to the Baylands Goals Report, to incorporate climate change considerations.

Uplands Habitat Goals Project

The San Francisco Bay Area Upland Habitat Goals Project has completed several reports over the past decade, with more underway, using a science-based process based on existing and new data supplemented by expert opinion to recommend the types, amounts, and distribution of upland habitats, linkages, compatible uses, and the ecological processes needed to sustain diverse and healthy communities of plant, fish, and wildlife resources in the Bay Area.

The project's objectives are to:

1) increase the acreage of protected lands by increasing public and private funding for habitat acquisition and restoration; and

2) develop an increased awareness of key habitats among land management agencies and local jurisdictions charged with land use planning. The GIS database and reference documents developed by this project are intended to be decision-support tools to inform voluntary, non-regulatory investments, protection strategies, and management policies of public resource agencies, nonprofit conservation organizations, local government, legislators and private foundations seeking to preserve, enhance, and restore the biological diversity of upland habitats before development eliminates remaining opportunities.

The San Francisco Bay shoreline has multiple habitat types: sand, cobble, and open water.

benefits to linking restoration projects in subtidal habitats to those in adjacent marshes and uplands. These benefits arise from landscape-scale ecological processes, i.e., processes that extend over more than one habitat type. For example, restoration at a nearshore subtidal site may enhance sediment retention that would favor persistence of an adjacent marsh.

Carrying this further, it may also be possible to design restoration of subtidal habitats not only to protect and interact with marshes and uplands, but also as a substitute for or a complement to seawalls and breakwaters used to protect vulnerable shorelines. With rising sea level (Appendix 2-2) and ongoing loss of sediment (Chapter 4), the value of shoreline protection and the consequences of erosion at unprotected shorelines become more apparent.

An Integrated Habitat Approach to Restoration

Most of the habitat restoration projects implemented in and around San Francisco Bay in the last 40 years have focused on single habitat types such as marshes and riparian zones. A few large regional restoration projects have incorporated planning for multiple habitats across landscapes, including the South Bay Salt Pond Restoration Project and the Dutch Slough Restoration Project. Integrating restoration between subtidal and nearby marsh and upland habitats may provide ecological benefits, as discussed below, and the resulting interactions may result in cost savings compared to equivalent isolated restoration projects.

Many ecosystem processes occur at a larger scale than individual habitats. These processes include:

- Sediment transport and retention (Appendix 2-1, sediment narrative) at nested scales: sediment supply and loss occur at the scale of the estuary; the major estuarine basins have water circulation cells that cause them to gain or lose sediment somewhat independently of each other; within these basins are regions where sediments accumulate or are eroded over seasonal or longer periods; and at smaller scales, marshes exchange sediment with nearby shallow subtidal regions.

- Biogeochemical processing of materials: marshes are sites of transformation of substances between alternative chemical forms. These substances may enter a marsh from the adjacent waters in one form, become transformed, and leave the marsh in a different form. This can affect nutrient availability, oxygen supply, and the availability of organic carbon to microbes both within the marsh and in nearby waters.

- Net organic production: marshes produce vast amounts of organic carbon. The importance of this carbon to the food webs of adjacent waters has been debated for decades. The magnitude and direction of movement of organic carbon between marshes and adjacent waters, and the forms (living and non-living) and degree of bioavailability of this carbon, likely vary with the physical configuration of the site, biological components, season, and freshwater flow patterns (Dame et al. 1986). The key point, though, is that there are strong links between marshes and adjacent waters.

- Movement of organisms: mobile estuarine organisms including birds, fish, and shrimp move into marsh channels and onto marsh plains, feeding there and moving living biomass from the marsh to the open water. This process may be an important mechanism for exporting high marsh productivity to the open water in a form that is usable to higher organisms (Kneib 1997). Taken more broadly, movement of organisms links marshes and adjacent subtidal habitats with the major rivers feeding the bay (anadromous fish), a large swath of the Pacific Ocean (anadromous salmon), and the Canadian and Alaskan Arctic (migratory birds).

Subtidal eelgrass bed offshore from an intertidal rocky shoreline.

Restoration can be expensive, uncertain, and difficult; therefore it seems logical to design restoration projects to capitalize on links between nearby habitats. Subtidal habitats that increase bottom friction, mainly oyster reefs and eelgrass beds, could be placed so as to attenuate wind waves and thereby buffer tidal wetlands and creek mouths from erosion. The combination of marsh restoration and nearshore subtidal habitat restoration could create local zones of sediment retention, minimizing the need for ongoing intervention. Local concentrations of oysters on constructed reefs may increase water clarity, thereby increasing the amount of light available to nearby eelgrass beds.

An additional advantage of integrated restoration is to reduce the effects of habitat fragmentation. Extant marshes are small and geographically dispersed. Even after completion of the Baylands Goals Project, these habitats will not approach the extent and contiguity of pre-settlement marshes. Yet, connectivity among habitat elements is a key feature of ecological landscapes, where subsidies of nutrients, other substances, or organisms can cross habitat boundaries and enhance overall productivity (Polis et al. 1997). Although the magnitude of this enhancement would be difficult to measure at an integrated restoration site, the existence of these known links and the conceptual importance of subsidies and flows between habitats supports the integration of subtidal and marsh or riparian restoration. Integration may also help foster upslope migration of the marsh as sea level rises at some locations. Since this movement will require additional sediment, having an adjacent subtidal source or retention area for sediment may help the marsh grow at its upland edge.

Although integrated restoration seems promising, present knowledge is inadequate to design projects that will achieve the goals of this chapter. As with restoration of individual habitats, this suggests using an adaptive, phased approach in which learning at each phase provides input to decisions about the scale, scope, and design at the next phase.

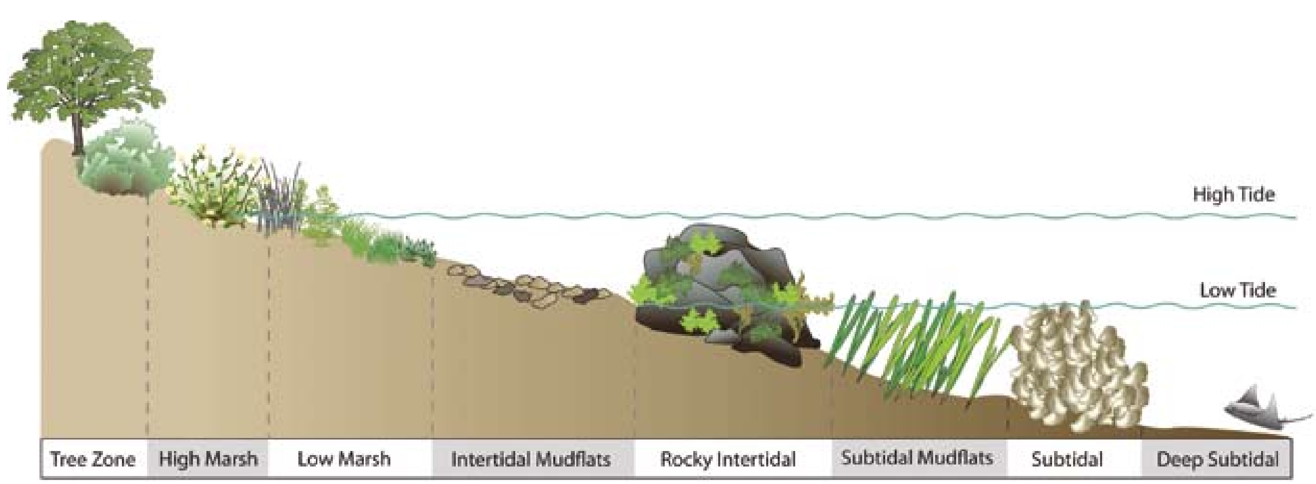

Figure 10-1: Conceptual cross-section of a living shoreline design.

Living Shorelines: Softening and Protecting Edges

People are likely to adapt to sea level rise and a decrease in sediment supply by increasing the height and extent of levees and seawalls to protect their property. These actions have consequences beyond the property boundaries. For example, seawalls reflect incoming wave energy, whereas a natural, gradually sloping shore absorbs and dissipates the energy (see also Chapter 6). The reflected wave energy is thereby available to erode unprotected shorelines elsewhere. As the degree of armoring increases, erosion of remaining unprotected shores is likely to increase. Furthermore, enhanced erosion immediately offshore from the armored shoreline realigns the distribution of sediments, which can result in unintended deposition in remote areas. These widespread consequences, such as transfer of deposition or erosion to other areas, represent an externality to the cost of the shoreline protection—a cost not borne by the property owner.

Although these effects have been known for a long time, alternative methods for protection of vulnerable shorelines have been slow in coming. A recent National Research Council publication on shoreline protection (NRC 2007) examines current practices for minimizing erosion and concludes with a call for alternative approaches at project to regional scales. They acknowledge that specific effects of hard structures on unprotected areas can be difficult to quantify:

> *In most areas, the scope and accessibility of information regarding the causes of erosion at specific sites and the overall patterns of erosion, accretion, and inundation in the broader region (estuary, lagoon, littoral cell) [are] insufficient to support the development of an integrated plan for managing shore erosion. (NRC 2007, Executive Summary)*

The NRC report nevertheless recommends alternative approaches including the use of soft structures and incorporation of living materials into shoreline protection schemes. These schemes can be characterized as "living shorelines" (Erdle et al. 2008; see also http://www.habitat.noaa.gov/restoration/techniques/livingshorelines.html) that can 1) protect adjacent vulnerable shorelines; 2) minimize externalities such as the transfer of erosion; and 3) increase the extent of potentially valuable subtidal habitat (see Chapters 7 and 8 for a discussion of the potential value of these habitats).

The idea that living materials can help protect shorelines is not new, as there are many examples of shoreline protection by naturally-occurring barriers (see sidebar). However, the use of natural materials in restoration, construction, or enhancement of shorelines for protection of vulnerable areas is not yet widespread (see, for example, Williams and Thom 2001). Reasons for this include tradition, perceptions (or reality) of high cost, and lack of knowledge necessary to design such structures (NRC 2007). In the meantime, however, integrated living shoreline projects have been successfully tested by NOAA's Community-based Restoration Program, US Fish and Wildlife Service's Coastal Program, Chesapeake Bay Foundation, North Carolina Coastal Federation, North

NATURE'S LIVING SHORELINES

Nature provides many examples of shorelines protected by living habitats. The most obvious example is coral reefs. Reefs grow in all tropical oceans, and typically consist of a massive, rocky bed of limestone from previous reef development, and a crown comprising corals and coralline algae in a strong, wave-resistant matrix. Two elements of a coral reef are essential for its function in shoreline protection. First, the coral/algae matrix grows to approximately mean sea level, maintaining a barrier to waves. Second, the surface of the reef is rough at all spatial scales, maximizing friction and extracting most of the energy from waves.

The protective value of coral reefs can be seen most clearly on atolls, where human populations can survive on land that is at most a few meters above sea level. Even during hurricanes, overtopping of atolls by wind waves is surprisingly uncommon (although this may change with sea-level rise). Low-lying areas of high islands and mainlands can also be protected by fringing or barrier reefs.

Other examples of natural shorelines that inhibit erosion (or even trap sediments) include mangrove swamps, extensive tidal marshes, and river deltas.

This degraded shoreline edge could be improved using integrated habitat restoration techniques.

A healthy shoreline edge with oysters and seaweed.

Carolina Division of Coastal Resources, Florida Department of Environmental Protection, and other funding and restoration partners for more than two decades on the East Coast and areas of the Gulf Coast (Erdle et al. 2008).

The interest in restoration of oyster and eelgrass beds and the need for increasing shoreline protection in San Francisco Bay present an opportunity for beginning experimental work at the pilot project scale to design living shorelines. However, both the quantitative effects of hard structures (and therefore the magnitude of externalities in relation to the cost of the structures) and the best design practices for minimizing these effects are poorly known. As with restoration of oyster and eelgrass beds and integrated shorelines, this implies a need for a careful, phased approach using an adaptive management framework (Chapter 2) to ensure that fundamental questions about benefits and design can be answered early, and knowledge gained in early phases can improve practices and outcomes in later phases.

Coral reefs are one type of living shoreline.

Examples of Living Shoreline Pilot Projects that Could be Attempted in San Francisco Bay

Living shorelines represent a new approach to shoreline stabilization. Yet knowledge of their benefits and best practices is scanty and is specific to locations other than San Francisco Bay. This suggests that we develop and test small pilot projects at sites vulnerable to erosion. These projects would test the use of biological treatments in place of hard structures, and test new or modified structures made of materials and in locations that may provide expanded habitat benefits. Many permitting and regulatory issues must be addressed as these pilot projects move forward, including issues of site suitability, material suitability, risk assessment, effectiveness of scale, habitat conversion and mitigation, and potential conflicts in protecting newly created habitat and structures that require ongoing, long-term maintenance.

Top: Volunteers plant a living shoreline.

Center: The Seattle Seawall tests various substrate types and orientations to identify which provide the best habitat for subtidal species.

Bottom: A living dock in Florida uses Virginia oysters to filter the water.

Classes of projects that could be attempted at the pilot scale include the following:

Living breakwaters are structures placed parallel to the shore in medium- to high-energy open-water environments to dissipate wave energy while providing habitat and erosion control benefits to an ecosystem. These breakwaters are constructed of native rock or artificial reef structures seeded with oyster spat. Quiescent areas between the breakwaters and the shoreline could be planted with SAV and marsh grasses to create intertidal and marsh habitat for aquatic organisms.

Living seawalls incorporate subtidal habitat into structures built for the primary purpose of protecting shorelines. For example, a recent experiment in Seattle installed panels along a seawall with various shapes and textures to determine rates of colonization by marine flora and fauna. Troughs were also installed extending out from the face of the seawall to mimic shallow water habitats that have largely been lost along the Seattle shoreline. The potential benefits could include greater nearshore productivity and trapping of sediment and organic matter. (http://www.cityofseattle.net/Transportation/seawall.htm)

Living docks are exemplified by a project in West Palm Beach, Florida. The dock is designed to support natural systems such as mangroves, grasses, and oysters that create habitat and provide water-filtration services. The living dock system is multi-layered and includes geotextiles enclosing a special soil mix for floating mangroves and marsh plants. Embedded within the geotextile layers are oyster shells from restaurants, which were placed to help spur natural oyster growth.

Oyster balls made of concrete and shell can be used at living shoreline sites to decrease wave energy while enhancing fish and oyster habitat. These structures can dissipate wave energy, decreasing coastal erosion and providing a reduced-energy area behind them in which newly planted vegetation can grow. As discussed in Chapter 7, key research questions need to be answered as to the benefits of the reef structures themselves versus the benefits from the settled oysters.

Biologists and volunteers deploy a Reef Ball™ that will attract native oysters.

Tidal wetlands include subtidal sloughs and channels that connect to offshore subtidal habitats.

A sand beach restoration project at San Francisco, south end of Pier 94, three months post-nourishment (2006).

Submerged aquatic vegetation such as eelgrass dampens wave energy, stabilizes nearshore sediments, improves water quality via nutrient uptake, and provides food and shelter for other marine organisms (Chapter 8). When these are used in conjunction with other living shoreline components such as marsh grasses, a natural shoreline buffer may be created that reduces coastal erosion and stabilizes sediments via root growth.

Intertidal sand beach or subtidal sand habitat is included in this discussion as an alternative to hard shorelines, although the principal function arises through geophysical rather than biological processes. Beaches and marsh berms bordering tidal marshes provide the first line of dynamic defense against wind-wave erosion during extreme high tides and storms. Nourishment of erosion-prone marsh scarps or berms with sand, gravel, or shell is likely to provide or lead to erosion buffering, shorebird refuge, and vegetation cover, and to approximate long-lost connections between beach and marsh (Baye 2007). A few pilot projects to replenish sand beaches have been conducted in San Francisco Bay, including at Coyote Beach in San Mateo and Pier 98 in San Francisco. Future projects could be designed with more specific focus on sand transport pathways and the benefits and impacts to the adjacent offshore subtidal areas.

Enhanced intertidal or subtidal rocky habitat. The extent of natural rock is limited to a few areas mainly in central San Francisco Bay (Chapter 5). Some rock has been placed into artificial configurations at sites such as Albany Beach. Opportunities exist to reuse and reconfigure existing native rock at sites where shoreline restoration is being planned and at tidal elevations that maximize colonization by native flora and fauna.

Rationale for Establishing Goals for Subtidal-Wetland Integration

In contrast to the habitats discussed in Chapters 4-9, the decision tree (Chapter 2) provides no guidance for integrating subtidal habitats with marshes and riparian habitats or for establishing living shorelines. However, the high degree of uncertainty, even about appropriate methods to conduct pilot projects under these topics, requires the application of adaptive management principles for these pilot projects to be most effective.

Goals for integration generally focus on pilot-scale projects to test concepts and practices at a large enough scale to be meaningful. This contrasts with the shellfish and SAV chapters (7 and 8), which call for a phased approach that moves beyond pilot projects once the requisite knowledge has been developed. Here the degree of uncertainty about the success of integrated restoration is sufficient to preclude planning for larger-scale projects until and unless the success of early pilot projects can be convincingly demonstrated.

The knowledge-gathering element of the pilot projects should focus in particular on the synergistic aspects of integrated restoration. That is, restoration of a particular habitat type (for example eelgrass) is assumed to proceed under an adaptive framework in which an explicitly designed process gathers knowledge about the ecosystem benefits of and best practices for restoring that habitat. In integrated restoration additional information must be gathered on the extent to which this restoration project achieves goals that cross habitat boundaries, such as enhancing connectivity with marshes or protecting vulnerable shorelines.

As with habitat-specific restoration, the degree of uncertainty about integrated restoration suggests that pilot projects lacking the full adaptive management framework will fail to provide the knowledge needed to proceed beyond the pilot stage. The only possible justification for conducting pilot projects, which are intended eventually to lead to larger-scale projects, is to develop the knowledge to determine whether a shift to a larger scale is warranted. This gives strong justification to a recommendation not to undertake such projects without the requisite pre-project analyses, monitoring and investigations during and after construction, and post-project analysis.

A healthy tidal marsh includes many subtidal channel edges.

Goals in this chapter could be refined by the introduction of expertise from places where these approaches have been tried.

Marshes are eroding around the bay's edges.

Therefore a valuable initial step is to host a workshop on these approaches. Invited participants from other locations in the U.S. and overseas would be asked to present a summary of their findings, and local participants would provide some context on current conditions and challenges. The final step in such a workshop would be to develop a set of recommendations specific to San Francisco Bay.

The specific restoration actions and sites listed below include considerations such as: (1) presence of and knowledge of existing subtidal resources; (2) presence of current pilot subtidal restoration projects that could be expanded; (3) proximity of subtidal resources to wetland restoration sites recommended by the Baylands Habitat Goals Project; and (4) for living shorelines, proximity to areas of current or anticipated shoreline erosion. Research goals focus first on the overall benefits of integration, and secondarily on further developing site criteria and best techniques for living shoreline designs and monitoring.

Science Goals for Subtidal-Wetland Integration

SUBTIDAL-WETLAND DESIGN INTEGRATION SCIENCE GOAL 1

Understand the ecosystem services supported by marsh-subtidal integration and living shorelines, and in what quantities.

Question A. What quantitative synergies in ecosystem services arise when subtidal habitats are linked to marshes and riparian areas?

The basic question of which ecosystem services are provided by the individual habitats is addressed in each of the habitat chapters. Is it possible to measure the additional benefits of locating habitat restoration sites adjacent to wetlands? Are there disadvantages, and do the benefits of such location outweigh other criteria for site selection?

Question B. Which ecosystem services are provided by living shorelines, and in what amounts?

This question should be addressed repeatedly throughout the adaptive management process for living shorelines.

SUBTIDAL-WETLAND DESIGN INTEGRATION SCIENCE GOAL 2

Develop best practices for integrating subtidal restoration with adjacent wetlands.

Question A. What characteristics of shorelines lend themselves to cross-shore integration?

Question B. Which wetland sites are likely to be most vulnerable to long-term changes in sea level and sediment supply?

Investments in tidal wetland restoration projects need to be protected in the face of climate change and other future changes to the bay.

Question C. Which approaches result in the most effective and persistent wetland-subtidal restoration projects?

SUBTIDAL-WETLAND DESIGN INTEGRATION SCIENCE GOAL 3

Develop best practices for pilot projects to create living shorelines.

Question A. What criteria should be used to choose locations for living shorelines?

Question B. How does the physical configuration of a living shoreline influence its ability to protect inshore areas, and what are its ancillary effects on other habitats?

Many habitat types can occur at the same location: eelgrass, native oysters, and macroalgal beds.

Relatively little is available in the scientific literature on the design and construction of living shorelines, although outreach programs on these topics are available at several universities, and NOAA has funded several projects. Most of these efforts are on the East and Gulf coasts. While some lessons from these projects will be applicable in the bay, several important differences (for example in tidal range, sediment characteristics, plant types) may affect the performance of different designs.

Question C. How self-sustaining are the alternative designs?

The ideal design would result in living shorelines that are self-sustaining or require minimal human intervention. Some periodic maintenance may be needed, such as cleaning shell reefs or placing clean dredged sediment to provide a source of sediment to maintain habitats.

Restoration Goals for Subtidal-Wetland Integration

SUBTIDAL-WETLAND DESIGN INTEGRATION RESTORATION GOAL 1

Explore the integration of upland, intertidal, and subtidal habitats in San Francisco Bay.

- Subtidal-Wetland Design Integration Restoration Objective 1-1: Select sites that have the greatest opportunities for integrating subtidal habitat with other restored or important habitats for pilot subtidal restoration projects near locations identified by the San Francisco Baylands Ecosystem Habitat Goals Project.

  Possible locations include:

  - San Pablo Bay: study potential resources and restoration activities in areas offshore from Sears Point, San Pablo Bay National Wildlife Refuge and Tubbs Island, and other restoration sites.
  - Corte Madera area: Muzzi Marsh, Corte Madera Ecological Reserve, Heard Marsh: existing wetlands and restored eelgrass, link to living shoreline project
  - Richardson Bay: wetland restoration linked to existing oyster/eelgrass populations
  - Breuner Marsh and Point Molate: link to Point San Pablo eelgrass bed
  - Eastshore State Park: wetland restoration linked with oyster and eelgrass restoration, creek daylighting
  - Central and North Bay Islands: link rocky habitat with eelgrass and oyster beds
  - South Bay Salt Pond sites; Eden Landing and other sites: link to southernmost eelgrass population, native oyster restoration

- Subtidal-Wetland Design Integration Restoration Objective 1-2: Support and promote integration of subtidal habitat design and subtidal enhancement, restoration, and monitoring into tidal wetland restoration projects around the bay.

  Subtidal-Wetland Design Integration Restoration Action 1-2-1: At appropriate sites, incorporate project elevations that include gradual slopes across a range of depths, linking the shoreline edge to shallow and deep waters, and allowing for a variety of topography and micro-habitats to benefit multiple species. Some sites, such as rocky headlands with naturally steep slopes, would not be appropriate for this treatment.

  Subtidal-Wetland Design Integration Restoration Action 1-2-2: Incorporate a variety of subtidal channel configurations into tidal wetland restoration.

A typical salt pond levee with compacted soil covered in invasive crystalline iceplant. There are many opportunities to test new multi-habitat restoration approaches within the South Bay Salt Pond Project.

Subtidal-Wetland Design Integration Restoration Action 1-2-3: Reduce or modify hard artificial structures within restoration sites to protect and improve subtidal channel habitat functions. See Artificial Structures Protection Goals, Chapter 6.

Subtidal-Wetland Design Integration Restoration Action 1-2-4: Design tidal wetland restoration projects to better enhance and improve transition (edge) zones between tidal and subtidal habitat, and include multiple arrays of small habitat types (such as eelgrass beds, native oyster beds, kelp and algal fringes, rocky intertidal, and intertidal sandy beaches).

Subtidal-Wetland Design Integration Restoration Objective 1-3: Increase regional coordination and collaborative planning to advance subtidal-wetland integration.

SUBTIDAL-WETLAND DESIGN INTEGRATION RESTORATION GOAL 2

Integrate habitat flexibility to increase resilience in the face of long-term change at habitat restoration sites around the bay.

- Subtidal-Wetland Design Integration Restoration Objective 2-1: Design habitat restoration projects to account for long-term changes including sea level rise and loss of sediment, by increasing resiliency of existing habitat types and facilitating upslope habitat migration.

Subtidal-Wetland Design Integration Restoration Action 2-1-1: Design projects to include subtidal habitats and natural bioengineering techniques that buffer wave action and increase sediment deposition to minimize shoreline and wetland erosion.

Subtidal-Wetland Design Integration Restoration Action 2-1-2: Integrate natural sedimentation processes into restoration designs to capture sediments and minimize erosion. For example:

- Avoid siting restoration projects or breach locations in highly erosional areas.

- Develop designs that maximize depositional areas and integrate local creek mouths.
- Promote use of clean locally-dredged sediment to supplement sediment where appropriate.
- Design gradual slopes that slow wave action and reduce erosion.
- Use bioengineering techniques such as eelgrass plantings and rock or oyster shell to stabilize sediment.

Subtidal-Wetland Design Integration Restoration Action 2-1-3: Monitor and evaluate existing subtidal resources and habitat types to track impacts of sea level rise to subtidal habitats that occur within and adjacent to selected tidal wetland restoration projects.

SUBTIDAL-WETLAND DESIGN INTEGRATION RESTORATION GOAL 3

Explore the use of living shoreline projects as a way to achieve multiple benefits in future shoreline restoration.

- Subtidal-Wetland Design Integration Restoration Objective 3-1: Evaluate living shoreline and associated techniques outlined above by implementing five small-scale pilot projects in San Francisco Bay by 2015.

Potential living shorelines sites:

- Corte Madera Bay, Corte Madera
- Eastshore State Park, multiple sites
- South Bay Salt Pond Project (Eden Landing Ecological Reserve, Alviso Pond Complex, Ravenswood Pond Complex)
- Albany Beach, Albany
- Breuner Marsh, Richmond
- Crown Beach, Alameda
- Former Naval Air Base lands, Alameda
- Hunters Point and Yosemite Slough areas, San Francisco
- Arambaru Island, Tiburon
- Sears Point, San Pablo Bay National Wildlife Refuge
- Suisun Marsh

(*See Figure 4-5, Chapter 4: Map of suggested locations for pilot intertidal sand beach enhancement and living shorelines*).

Subtidal-Wetland Design Integration Restoration Action 3-1-1: Incorporate multiple habitat types into pilot living shoreline designs; test effectiveness at buffering wave action, stabilizing sediments, and providing habitat; and evaluate success of restoration techniques and materials, including:

- soft substrates (mudflat, shell hash, sand)
- native rock and cobbles, stone, stone sills
- artificial structures (reef balls, reef blocks, etc.)
- native oyster and mussel treatments
- native eelgrass treatments
- native macroalgal treatments

Subtidal-Wetland Design Integration Restoration Action 3-1-2: Incorporate living shoreline techniques to retain mud and sand from natural deposition or from sand replenishment activities.

- **Subtidal-Wetland Design Integration Restoration Objective 3-2:** If small pilot projects prove successful at achieving the three purposes discussed above, expand small-scale projects or implement 10 mid-scale living shoreline and living breakwater projects in San Francisco Bay by 2020.

- **Subtidal-Wetland Design Integration Restoration Objective 3-3:** Pending the results of evaluations of pilot-scale studies, incorporate living shoreline components and naturalized habitat into the design of new and replacement shoreline protection structures.

Eelgrass restoration can be integrated into rocky intertidal shorelines or tidal wetlands.